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Codebook Design for Millimeter-Wave Channel Estimation With Hybrid Precoding Structure

- Proposed a beam search method to search one multipath component (MPC) at a time with the hybrid precoding structure.
- Precoding matrices and combining matrices selected from Tx and Rx codebooks, respectively.
- Channel Estimation:

$$\mathbf{Y} = \sqrt{P}\mathbf{W}_{BB}^{H}\mathbf{W}_{RF}^{H}\mathbf{H}\mathbf{F}_{RF}\mathbf{F}_{BB}\mathbf{S} + \mathbf{W}_{BB}^{H}\mathbf{W}_{RF}^{H}\mathbf{Z} \tag{1}$$

  where **S** is a set of orthogonal training sequences (in each row).
- Received signal at the i^{th} RF chain is

$$[\mathbf{Y}]_{i,:} = \sqrt{P}\,[\mathbf{W}_{BB}]_{:,i}^{H}\,\mathbf{W}_{RF}^{H}\mathbf{H}\sum_{m=1}^{M_{RF}}\mathbf{F}_{RF}\,[\mathbf{F}_{BB}]_{:,m}\,[\mathbf{S}]_{m,:} \tag{2}$$

$$\rho_{i,j} = [\mathbf{Y}]_{i,:}\,[\mathbf{S}]_{j,:}^{H} \tag{3}$$

$$(j^{*}, i^{*}) = \underset{(j,i)}{\text{argmax}}\,|\rho_{i,j}|^{2} \tag{4}$$

- Channel estimate is given by

$$\mathbf{H}_1 = \rho_{i^*,j^*}\mathbf{a}\left(N_{AN}, -1 + \frac{2i_R - 1}{N_{AN}}\right)\mathbf{a}\left(M_{AN}, -1 + \frac{2j_T - 1}{M_{AN}}\right) \tag{5}$$

  where the arguments of the steering vectors **a** are the outputs of the beam search algorithm.
- To reduce the training overhead, a hierarchical Tx/Rx codebook is defined, where codebook has different layers.
- Given the target beam pattern, design $\mathbf{F}_{RF}$ and $\mathbf{F}_{BB}$. Hierarchical codebook design using beam widening with the multi-RF chain sub-array (BMW-MS) technique.
- Main idea is to divide the large RF weight vector of each RF chain into multiple sub-vectors (sub-arrays), and these sub-arrays can point at different directions, such that a wider beam can be shaped.
- Two solutions (Low-complexity search and closed-form) are proposed to solve for the coefficients to determine the coefficients for the BMW-MS approach.

Distributed MIMO Multicast With Protected Receivers: A Scalable Algorithm for Joint Beamforming and Nullforming

- Distributed algorithm in which each transmitter iteratively adapts its complex transmit weight using common aggregate feedback messages broadcast by the targets, and the local knowledge of only its own channel gains to the targets.
- System Model:
  - Distributed array of N single antenna transmitters.
  - M single antenna receivers, M_1 beam targets, $(M - M_1)$ null targets.
  - In the k^{th} time slot, all transmitters broadcast after precoding, a common complex baseband signal m_k. At the null targets, the received signal must be 0.
- Each transmitter adjusts the transmit weights to minimize the quadratic cost function

$$|m_k|^2 \left\{ \sum_{j=1}^{M_1} |r_j[k] - b_j|^2 + \sum_{j=M_1+1}^{M} |r_j[k]|^2 \right\} \tag{6}$$

- Each time slot has transmission phase and time interlaced feedback phases from all the receivers.
- Adjustments of the precoding gains are effected through the distributed gradient descent minimization of (6).

$$x_i[k+1] = x_i[k] - \mu \sum_{j=1}^{M} h_{ij} \left(s_j[k] - b_j \right). \tag{7}$$

- $b_j = 0$ for null targets and specified non-zero values for beam targets.
- Geometric interpretation of the optimum solution, convergence analysis in the noiseless and noisy cases, convergence speed with deterministic channels and asymptotic results for Rayleigh fading channels are discussed in the analytical characterization section.

The Degrees of Freedom of the K-User MIMO Cyclic Z-Interference Channel Under Perfect and Delayed CSIT Assumptions

- DoF region for three users and the sum and symmetric DoF for K users obtained for the MIMO cyclic Z-interference channel (CZIC) with M Tx antennas and N Rx antennas under perfect and delayed CSIT assumptions.
- New communication schemes based on interference alignment developed and shown to be DoF-optimal for all choices of the number of antennas.
- Channel model:

$$Y_i(t) = H_{ii}(t)X_i(t) + H_{ij}(t)X_j(t) + Z_i(t) \tag{8}$$

- Main Results:
  - An outer bound for the DoF region of the K-user CZIC with perfect CSIT is given by the following inequalities:

$$d_i \leq \min\left(M_i, N_i\right) \tag{9}$$

$$d_i + d_{i\oplus 1} \leq \max\left(M_{i\oplus 1}, N_i\right) \tag{10}$$

$$\tag{11}$$

- An outer bound for the DoF region of the K-user CZIC with delayed CSIT is given by (9), (10) and the following inequality:

$$\frac{d_i}{\min(N_i, M_{i\oplus 1})} + \frac{d_{i\oplus 1}}{\min(N_i + N_{i\oplus 1}, M_{i\oplus 1})} \leq \frac{\min(N_i, M_i + M_{i\oplus 1})}{\min(N_i, M_{i\oplus 1})} \tag{12}$$

- DoF regions of the following channels are characterized using the outer bounds given above.
    - 3-user (M, N)-CZIC with perfect CSIT.
    - 3-user (M, N)-CZIC with delayed CSIT.
    - Symmetric DoF of the K-user (M, N)-CZIC with perfect and delayed CSIT.
- Proposed communication schemes that achieve the DoF region of the 3-user (M, N)-CZIC with perfect CSIT (for various ranges of $\frac{M}{N}$).
- Proposed communication schemes that achieve the DoF region of the 3-user (M, N)-CZIC with delayed CSIT for all ranges of $\frac{M}{N}$.

Other Interesting Papers

1. Multiplexing and diversity gains in noncoherent massive MIMO systems.
2. Uplink Performance of Wideband Massive MIMO With One-Bit ADCs.
3. Deterministic Pilot Design for Sparse Channel Estimation in MISO/Multi-User OFDM Systems.
4. Efficient Channel Estimation for Reconfigurable MIMO Antennas: Training Techniques and Performance Analysis.
5. Distributed MIMO Broadcasting: Reverse Compute-and-Forward and Signal-Space Alignment.
6. Analysis and Optimization of Caching and Multicasting in Large-Scale Cache-Enabled Heterogeneous Wireless Networks.
7. Stopping Rule-Based Iterative Tree Search for Low-Complexity Detection in MIMO Systems.